PATENT SPECIFICATION

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COMPLETE SPECIFICATION

A Slant-Shaft Rotary Piston Engine

We, NSU WERKE AKTIENGESELLSCHAFT, of Neckarsulm/Württemberg, Germany, a German company, and FELIX WANKEL, of Bregenzerstrasse 82, Lindau-Bodensee, Germany, of German nationality, do hereby hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

The invention consists in a rotary piston engine having two or more working chambers both or all of which are bounded solely by an inner and an outer spherical surface which are concentric with one another and by conical surfaces on two rotors which revolve continuously and unidirectionally at different speeds having a fixed ratio to one another each about a respective axis, the two axes being inclined to one another and stationary relatively to one another and intersecting at the centre of curvature of the spherical surfaces.

In a preferred form of construction the cones are non-circular, their surfaces being of undulatory conformation so that several generatrices of one cone are in continuous sliding abutment with the surface of the other.

The said form of construction of the rotary piston engine according to the invention provides the basis for a further essential feature of the invention which consists in that one of the conical surfaces is that of a spherical trochoidal cone the characteristics of which depend upon the angle formed by the two cone axes and the relative speeds of revolution of the cones about the said axes, and that the associated cone is represented by or approximates the corresponding conical enveloping surface.

The above described conformation of the two cones enables abutment between them to be along definite fixed generatrices or edges of one of the cones so that narrow radial sealing strips may be provided along these lines. The presence of these strips is essential to enable the engine to function and widens the limits of accuracy to which the remaining surface elements must conform. Normally such radial sealing strips will have a width of a few millimetres. To ensure that these sealing strips actually make contact with the cooperating surface across the whole of their width and thereby reduce wear to a minimum it is preferred to modify the spherical boundary of the trochoidal cone by the generation of a parallel curve of the spherical trochoid. By suitably selecting the distance between the parallel curve and the original curve allowance can be made for the desired deviation of the sealing edge. Moreover, the spherical trochoid may be replaced by circular sectors of arc. The sealing edges of the associated rotor must then move in the direction of the normal of its surface.

Planar representation of the rotor forms is rendered difficult by the fact that the spherical surfaces and the boundary curves of the trochoidal rotor and the associated rotor are not developable and cannot therefore be commensurably projected on to a plane. However, the generation of the rotor surface can be described as follows:—

In Fig. 1 a first shaft is shown at 1, and 2 is the axis of a second shaft, the axes of the two shafts forming an angle α. The point of intersection 3 of the two axes is the centre of a sphere of radius r, which appears in the drawing as a circle 6. Let it be assumed that a tracing pen 5 is rigidly connected with the second shaft at the end of an arm 4. When the sphere 6 revolves about the axis of the shaft 1 and the tracing pen 5 simultaneously revolves about the axis 2 the pen will trace a spherical curve on the surface of the sphere, and this curve will be unicursal whenever the angular speed ratio between the two shafts is $n_1 : n_2$ where n_1 and n_2 are both positive whole numbers and n_2 exceeds n_1 by 1. These curves traced on the surface of the sphere are spherical trochoids with n lobes. According to the speed ratio n_1/n_2 the single tracing pen 5 may be replaced by a plurality of generating points

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rigid with the second shaft, all of which will trace out the same curve.

Now let it be assumed that all the points of the spherical trochoid traced out on the surface of the sphere are joined by straight lines with the centre of the sphere. These lines will then determine an undulating conical surface provided on a trochoidal rotor in accordance with the present invention. The form of the surface of an associated rotor between the abutting elements is that of the bevel gear which meshes with the trochoidal rotor (i.e. the envelope of the trochoidal rotor). According to the desired compression ratio the surface of the associated rotor may be made to withdraw from the flank of the bevel wheel to a greater or lesser extent.

Figs. 2 to 6 are examples of various forms and phases of the surfaces of such spherical trochoidal rotors and their associated rotors as used in slant-shaft rotary piston engines of which embodiments are described hereinafter with reference to Figs. 7 and 8, it is to be understood that these figures simply illustrate the form of and manner of co-operation between the conical surfaces, and are not actual illustrations of the rotors themselves. The numerical references conform with the references used in Fig. 1. However, the arm 4 with the tracing pen rigidly connected with axis 2 is replaced by an anti-sphere 4 and contact points at 5.

Fig. 2 represents a pair of rotor surfaces enclosing three working chambers, for operation at a speed ratio of 2:3, shown in such a relative position that the working chamber having the maximum volume apears on the left. In this phase the two other working chambers, only one of which appears in the drawing, enclose intermediate volumes.

Fig. 3 represents the same pair of surfaces in the same phase, the working chamber of greatest volume being seen from the front.

Fig. 4 again shows a phase of the same pair of surfaces where the working chamber with the smallest volume appears on the left, whereas

Fig. 5 represents the phase shown in Fig. 4 viewed from the side. A comparison between maximum working chamber volume (Fig. 3) and minimum working chamber volume (Fig. 5) illustrates the considerable compression ratio that can be achieved.

Fig. 6 represents a similar pair of surfaces designed to a speed ratio of 1:2. The spherical trochoid is located on the surface of a sphere 6 which revolves about the axis 1 whereas the associated rotor surface 4 and the generating point 5 revolve about the axis 2. The illustration shows the greatest chamber volume on the left and the smallest chamber volume on the right.

Fig. 7 shows a practical form of construction of a slant-shafted rotary piston engine according to the present invention, the engine being designed to a speed ratio between the two rotors of 2:3. The shaft of the first rotor is again indicated by 1, that of the second rotor by 2 and the centre of the sphere by 3. 6 represents an outer spherical shell of the first rotor, and 7 a concentric inner spherical surface thereof. The angle between the two shafts is α. In the position shown in the drawing the upper chamber 8 encloses maximum volume. The inner bevel gear annulus 9 creates the differential speeds of revolution of the two rotors. The casing 10 which is indicated diagrammatically contains the two bearings.

The admission and exhaust ports for the working medium are not shown. They may be provided in one of the rotors, on the inner or outer spherical surface, or in the surfaces of the cones.

The channel sections and the port apertures, as well as the timing, depend upon the purpose for which the engine is intended.

The position of the control openings in the spherical surfaces is determined by the purpose for which the engine is used. It depends on whether the engine is designed as a pump for incompressible media, a compressor or a four-stroke engine. For instance a rotary piston engine which is constructed in accordance with the present invention and in which the trochoidal rotor has the higher speed of rotation will be able to produce a four-stroke control solely by the relative movements of the two rotors.

WHAT WE CLAIM IS:—

1. A rotary piston engine having two or more working chambers both or all of which are bounded solely by an inner and an outer spherical surface which are concentric with one another and by conical surfaces on two rotors which revolve continuously and unidirectionally at different speeds having a fixed ratio to one another each about a respective axis, the two axes being inclined to one another and stationary relatively to one another and intersecting at the centre of curvature of the spherical surfaces.

2. A rotary piston engine as claimed in Claim 1, in which at least one of the spherical surfaces is rigid in rotation with one of the rotors.

3. A rotary piston engine as claimed in Claim 2, in which both spherical surfaces are rigid in rotation with one and the same rotor.

4. A rotary piston engine as claimed in any of the preceding claims, characterised in that the fixed ratio of the speeds of revolution of the two rotors is $n_1:n_2$, where n_1 and n_2 are both positive whole numbers and n_2 exceeds n_1 by 1, and that the surface of one of the rotors has the form of a spherical trochoidal cone whereas the other rotor has at least one abutting edge in continuous sealing contact with said surface.

5. A rotary piston engine as claimed in Claim 4 modified in that the surface of the

one rotor has the form of a parallel surface to a spherical trochoidal cone and the abutting edge or edges of the associated cone are each provided with a radially disposed sealing strip in continuous sealing contact with said surface.

6. A rotary piston engine as claimed in Claim 4 or 5 characterised in that the surface of the trochoidal rotor consists by way of approximation of sections of circular cones and that the abutting sealing strips on the associated rotor extend along generatrices of the conical surfaces and are slightly movable in a direction at right angles to said generatrices.

7. A rotary piston engine as claimed in any one of Claims 1 to 6 characterised in that thin walled and elastically yielding sealing elements are interposed between the abutting conical elements and/or the truncated edges of the cones and the inner and outer spherical surfaces.

8. A rotary piston engine as claimed in any one of the preceding claims characterised in that gearing between the two rotors consists of an internal bevel gear annulus and a cooperating bevel gear.

9. A rotary piston engine as claimed in any one of the preceding claims characterised in that the opening and closing of the channels and ports for the working medium is effected by the relative movement of the inner and/or the outer spherical surfaces.

10. A rotary piston engine as claimed in any one of the preceding claims characterised in that the cone surfaces of both rotors are of generally undulatory conformation so that several fixed generatrices of one rotor are in permanent sliding abutment with the surface of the other rotor.

11. A rotary piston engine substantially as hereinbefore described and illustrated in Fig. 7 of the accompanying drawings.

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3 SHEETS This drawing is a reproduction of the Original on a reduced scale.
SHEET 1

Fig. 1

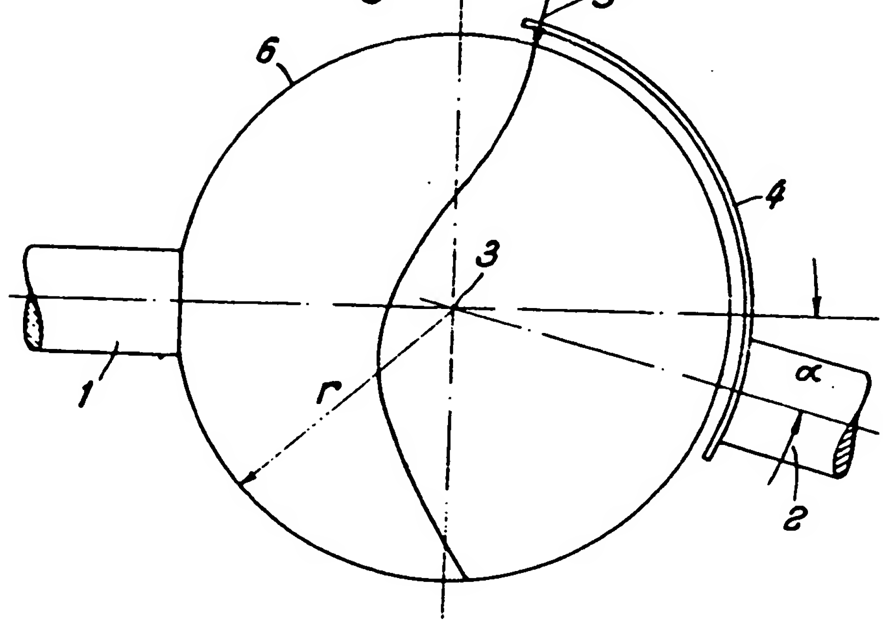


Fig. 2

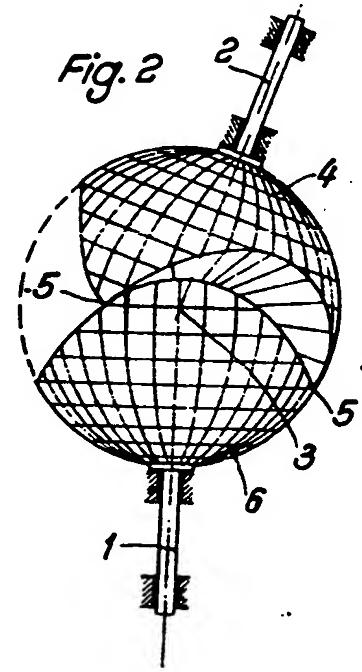


Fig. 3

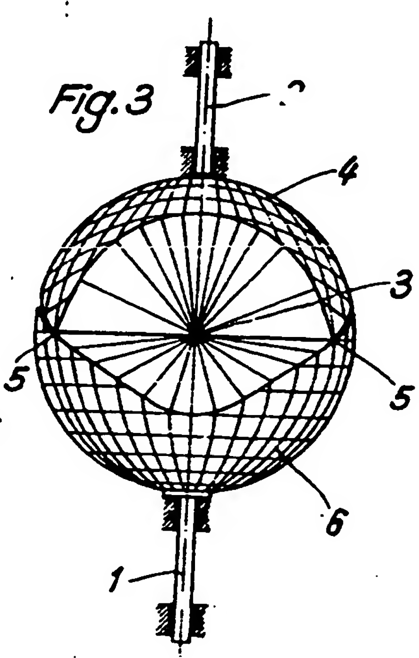


Fig. 4

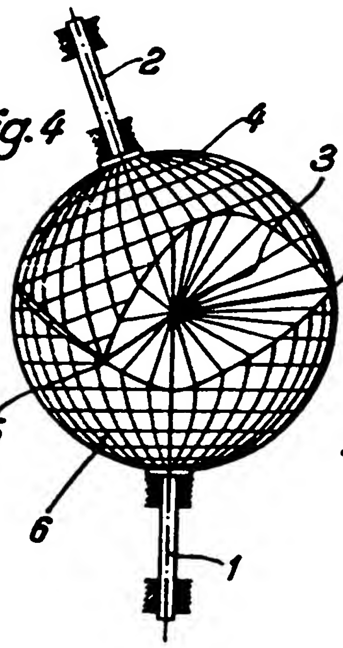


Fig. 5

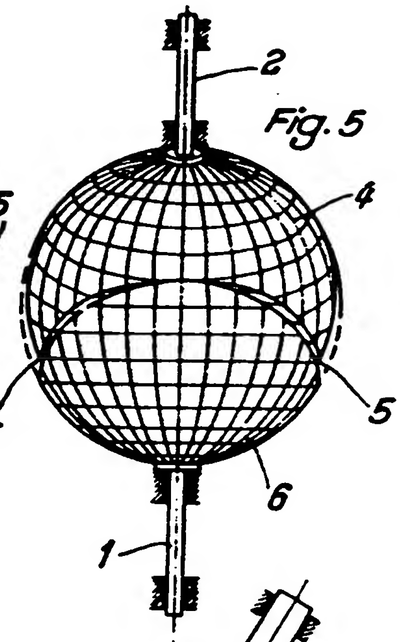
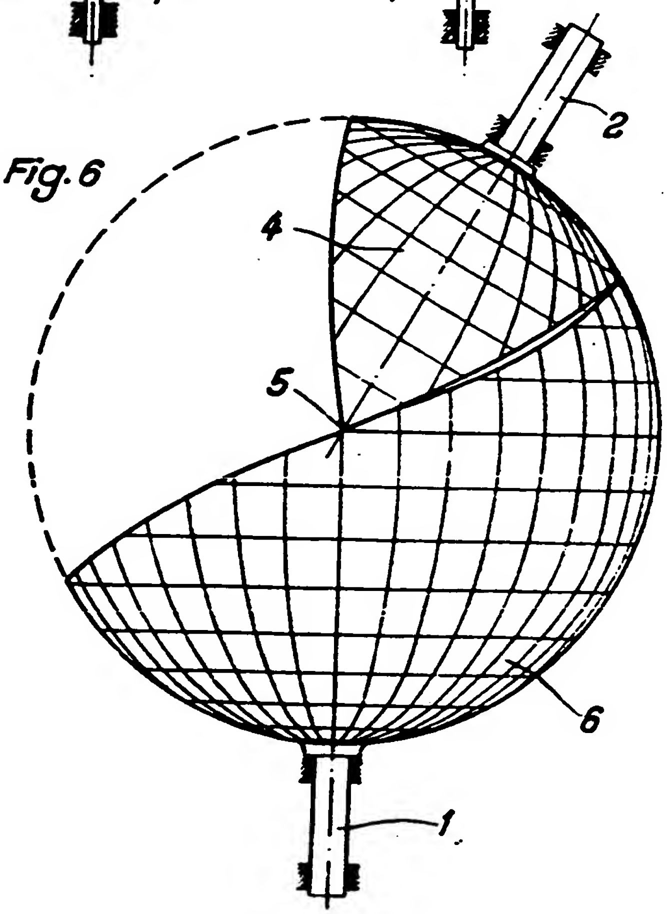


Fig. 6



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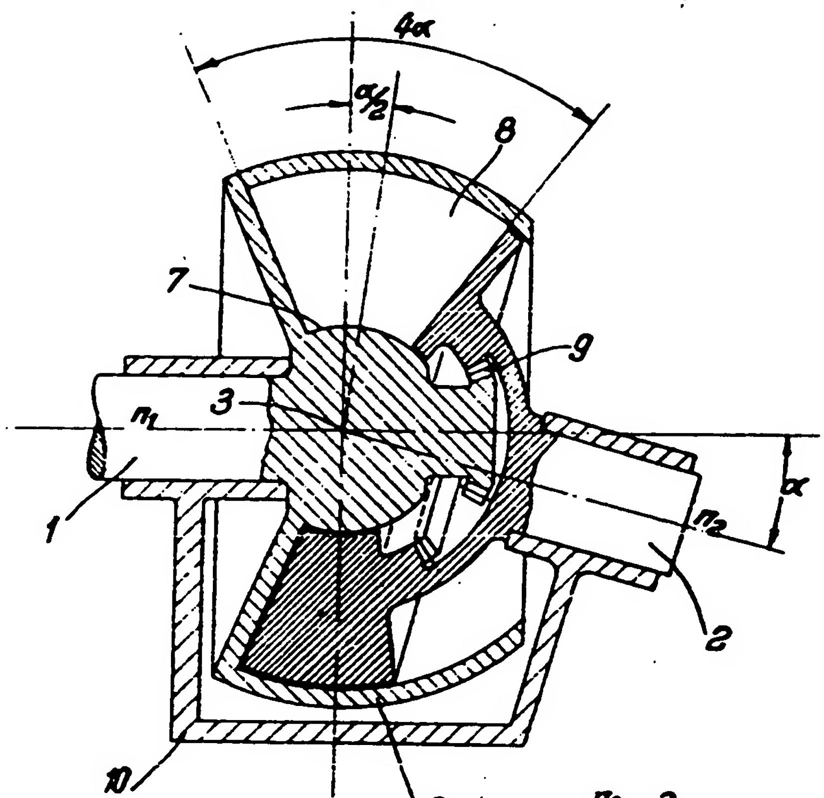
SHEETS 2 & 3

Fig. 7



$\frac{n_2}{n_1} = \frac{2}{3}$

$\alpha = 15^{\circ}$